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ABSTRACT

Two studies analyzed self-regulatory cognitions of students asked to study complex instruction texts; examined the relationship between self-regulation and performance; assessed self-regulatory processes during learning from text in detail; and examined how pictures integrated in instructional text were processed by learners with different degrees of domain-specific prior knowledge. In the first study, a "Computer-assisted Videoreconstruction" (CaV) procedure was used (presenting instructional material on a microcomputer display where the learner reads only a specially designed passage of text). Twenty subjects studied two structurally paralleled instructional texts (describing technical systems). For the first reading, subjects read the text aloud. After a comprehension test, subjects studied the second instructional text applying the method of "concurrently thinking aloud" (CTA), communicating all thoughts and feelings that occurred during the reading. Findings demonstrated that the frequencies of higher order self-regulative processes differed between CaV and CTA. In the second study, 32 university students with different degrees of domain-specific prior knowledge studied instructional text including comprehension-relevant pictures. Text was presented on a computer screen with a learner-controlled text window. Findings demonstrated significant relations between on-line variables of self-regulation assessed with CaV and learning performance in both text comprehension and knowledge application. (One figure is included, and 19 references are appended.) (MM)

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On-line and off-line assessment of self-regulation in learning from instructional text and picture

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On-line and off-line assessment of self-regulation in learning from instructional text and picture

Our research on self-regulation in learning from instructional text and picture is designed to identify cognitive, metacognitive and affective processes fostering text-comprehension and learning performance. The two studies with university students we will report about were conducted to meet three main objectives: Firstly, we intended to analyse self-regulatory cognitions of students asked to study complex instructional texts and to examine the relationship between self-regulation and performance. Secondly, we aimed at assessing self-regulatory processes during learning from text in detail. Therefore, we decided to conceive an integrated computer- and video-supported methodology adequate for registering behavioral learning activities on-line and cognitive processes off-line. Our third objective was to shed some light on the issue of how pictures integrated in instructional text are processed by learners with different degrees of domain-specific prior knowledge.

Relevance of self-regulation in learning from instructional text

Several researchers have been concerned with demonstrating the relevance of goal-adaptive self-regulation, metacognitive control and strategy monitoring during the study of texts as being important performance predictors. Fischer and Mandl (1984) attended to the question of how good and poor learners differ with respect to their strategy employment in learning from expository psychological texts. In a study with university students they applied structured, retrospective interviews to assess which techniques and strategies they employed while studying the text. Their findings demonstrate that successful and less successful learners did not differ in the amount of particular metacognitive thoughts (e.g. orientation, modification) as such. Rather, they differed in their quality of self-regulation: The good learners acted more flexible and goal-adaptive, their planning was more action-oriented and differentiated, and they scheduled learning time more effectively. Particularly, they focused primarily on comparing the desired outcome with the current state of knowledge and on finding possible corrective actions to bridge the gap between their cur-

rent and desired state of comprehension and learning. In contrast, unsuccessful learners focused their attention more often on action-distant, static information, e. g. registering single learning steps, without taking into account sufficiently task specific criteria and possible corrective measures. Besides, the weaker learners mentioned more often "dysfunctional" self-referenced thoughts in accordance with the concept of state-oriented action monitoring introduced by Kuhl (1987). Simons and Vermunt (1987) could give support to these results, especially concerning the relevance of affective components and action orientation in self-regulation as performance predictors in academic learning from texts. They report that less successful students were more often state-oriented in their thinking and foremost concerned with monitoring their emotions while successful students focused more on metacognitive control and monitoring their action plans.

In contrast to these findings, Buechel (1982) expressed some skepticism concerning the importance of metacognitive self-regulation in learning from text. Using the method of concurrent thinking aloud he assessed cognitions of vocational and technical high school students during the study of various written text material. Protocol analysis revealed that covert strategies like rereading, paraphrasing and information-completion appeared more often during learning compared to metacognitive activities. He concludes that the relevance of metacognitive processes and higher order knowledge components might be overestimated in research on strategic information processing.

In a study with secondary students Simons and Lodewijks (1987) investigated students' self-regulatory cognitions during learning from instructional text dealing with probability theory, and how these cognitions were related to performance. Students were asked to read and think aloud while studying the instructional material. Performance was assessed by means of a multiple-choice comprehension test. Most of the activities represented in the protocols were on-line processes. Very few pertained to cognitions that emerged before or after learning took place, e.g. planning, orientation, or evaluation. Results demonstrate that effective learning appeared to depend principally on the use and quality of self-monitoring processes. Good learners' monitoring processes were especially aimed at testing their understanding of the text, while students learning less well

tested mainly for literal retention.

De Jong and Simons (1988) report about a study concerned with differences between successful and less successful secondary school pupils in self-regulatory processes during text processing. The text consisted of instructions on how to use a computer keyboard and a text editor. Learning performance referred both to knowledge and application. Subjects were asked to think aloud during studying. The main differences between successful and less successful pupils occurred in orientation processes, especially with regard to reflection on prior knowledge and on gaps in prior knowledge. Successful pupils also showed more directing and testing activities: Differences also emerged for processes such as making summaries and process selection, i. e. deciding on the application of a specific strategy and changing from one on-going activity to another. De Jong and Simons (1988) conclude "that one gets the understanding of the different learning performances under control by inferring metacognitive processes out of on-line thinking-aloud protocols" (pp. 185).

Summing up, recent studies concerned with learning from instructional text demonstrate the relevance of cognitive and metacognitive processes for successful learning. These findings are in agreement with the "Good Strategy User" (GSU) model of Pressley, Borkowski and Schneider (1987) which focuses on declarative and procedural strategic, metastrategic, and knowledge components in complex task performance. Pressley et al. (1987) postulate that skilled learners often possess a rich repertoire of goal-specific and higher-order metacognitive strategies, know when, where and how to apply task-appropriate strategies at hand, and are capable to activate domain-related prior knowledge according to demands of the learning task. Beyond, Pressley et al. (1987) render special prominence to the relevance of affective, motivational, and attributive components during information processing, i.e. on-task strategic behavior must be supported by a positive affective-motivational orientation, including beneficial self-evaluations and conservation of interest despite of emerging difficulties.

In our opinion, the GSU-model offers an attractive framework to study learning from instructional text, because this model recurs both on cognitive and affective-motivational components of efficient task performance. Besides, it provides sufficient freedom to accentuate the relevance of domain-specific and general

strategies relevant in the field of learning from texts, like selective rereading, question-asking, summarizing, or differential allocation of attention.

In accordance with the GSU-model we define self-regulation as follows: Self-regulation in the context of learning from instructional text refers to the cluster of cognitive knowledge components, strategic activities and affective-motivational boundary conditions that are necessary and sufficient for the preparation, implementation, coordination, and evaluation of operative-strategic behavior intended to direct cognitive processing to successive knowledge acquisition and construction of domain-specific mental models. Consequently, effective self-regulation implies well-elaborated knowledge components, strategic learning capabilities, text-processing routines, and higher-order organization skills as important components to encode, integrate, remember, and recall complex text information.

Methodological issues

If we intend to capture critical component processes relevant for task-specific self-regulation in the domain of learning from complex instructional text on-line, methodological problems emerge, e. g. those resulting from the necessity to assess self-regulative activities unobtrusively and without changing the critical processes under investigation. Ideally, the chosen method should provide for process-centered and non-reactive data-assessment, avoiding interference with processing of instructional material and being adequate for pinpointing higher-order self-regulative processes.

Therefore, we designed the procedure of "Computer-assisted Videoreconstruction" (CaV). CaV is characterized by the following main steps: First, the instructional material is presented on a microcomputer display, using a "moving-window-paradigm" (Carpenter & Just, 1986). Thereby, the learner is asked to read only a clearly outlined, strongly contrasted and specially designed passage of the text ("learner-controlled moving text window"). For more precise registration of the text line in focus at a certain point of time, the out-of-focus passages are masked by reducing the contrast - nevertheless providing for some orientation concerning the structural features of the text page at hand. The

subject is also allowed to look forward and backward through the whole text at will, using a mouse device. During the learning phase reading behavior is analysed by the microcomputer on-line, for instance referring to selective allocation of attention or lookbacks (cf. Kunz, Schott & Hovekamp, 1987). Additionally, by means of a time-synchronized video system subjects' reading behavior is recorded from a side-perspective. Afterwards, computer analysis provides the experimenter with a sample of "critical events", where subjects spent disproportionately long amounts of time during their reading.

These events are selected because they may represent moments where learners shift from "automatic pilot" to "debugging mode" of text processing. According to Brown (1981) differences between expert and novice learners in reading to learn should emerge especially during the debugging states, where subjects are supposed to consciously deal with the text or focus reflectively on their ongoing cognitive activity. For instance, the different ways of "fixing comprehension failures" (Collins and Smith, 1981) are probably captured during these moments. In a subsequent, post-task video-stimulated recall phase subjects are asked to watch the video segments of these critical events and report retrospectively, i.e. off-line, about their situation-specific cognitions and feelings.

Study 1

Objectives

In the first study with university students CaV was applied to gather on-line data about learning activities during reading and to collect verbal report data indicative of self-regulative processes. Our main intention was to validate the method of CaV in comparison with the method of "concurrently thinking aloud" (CTA) that is often used as an on-line assessment method to study cognitive processes during learning from text (Afflerbach & Johnston, 1981, Garner, 1988).

The following two hypotheses were to be analysed: Firstly, we assumed that CaV is an appropriate method to obtain substantial information about person-specific self-regulation during learning. Besides, we supposed that there are some methodological advantages of CaV compared to CTA: CaV does not interfere considerably with

learning, data assessment is non-obtrusive, reacitivity is minimized, and media-supported reconstruction is appropriate for pinpointing higher order self-regulative processes during learning. Comparison of performance and protocol data collected by means of CaV versus CTA should demonstrate at least equivalence of both assessment procedures, possibly even superiority of CaV concerning elicitation of cognitions referring to self-regulative processes during knowledge acquisition. Secondly, we expected specific differences in self-regulation between good and poor learners: Good learners deal with the instructional material in a more flexible and strategic manner. They regulate their learning in accordance with objectives, task and contextual requirements more often and qualitatively more profoundly than poor learners. Consequently, we assumed that verbal report data collected with CaV would be adequate to give support to this hypothesis.

Method

In a repeated-measurement design subjects (N =20) were asked to study two structurally paralleled instructional texts describing technical systems (about 1500 words each). For both texts learning time was limited to twenty minutes. During the study of the first text subjects were asked to read the text aloud. In the video-stimulated recall-phase they were prompted to report retrospectively about their cognitions during a sample of five critical events, possibly indicating a shift from automatic pilot to debugging mode of reading. After having completed a comprehension test subjects were requested to study the second instructional text applying the method of "concurrently thinking aloud" (CTA). Subjects were asked to "communicate freely all thoughts and feelings coming up in their mind". Finally, the second comprehension test was administered.

Results

During learning several variables of reading behavior were assessed, particularly reading times, amount of looking forward and backward, skipping behavior, selective allocation of attention, etc. Statistical analysis of on-line data revealed that in the CaV condition subjects were dealing more flexibly with the text, e.g. demonstrated more forward skipping behavior ($t(19) = 2.78$, $p < .05$), more backward page skips ($t(19) = 2.34$, $p < .05$),

and more lookbacks ($t(19) = 2.48$, $p < .05$). Besides, they were more successful in a finally administered comprehension test ($t(19) = 11.98$, $p < .001$). Additionally, in comparison with the think-aloud condition they focused attention more selectively on criterion-relevant text passages ($t(19) = 4.40$, $p < .001$).

For the analysis of protocol data collected by means of CaV and CTA we specified a category sytem with reference to the GSU-model (Pressley et al., 1987). The category system consisted of the following main components: (1) specific regulation processes applied (e.g. orientation, planning, strategy execution, etc.), (2) strategic-functional focus of these processes (e.g. encoding, integration, retention), (3) affective-motivational mode of self-regulation (e. g. action- vs. state-orientation, c. f. Kuhl, 1987), and (4) specific knowledge applied (e.g. specific strategy knowledge, content knowledge, etc.). Data analysis demonstrated that CaV protocols included more verbalizations indicating metastrategic processing, i.e. "orientation" and "monitoring of failure of regulation" ($t(19) = 2.71$, $p < .05$, $t(19) = 2.32$, $p < .05$), while in think-aloud protocols "operative-strategic processes" (e.g. elaborations) emerged more often ($t(19) = -2.88$, $p < .05$). Although CaV and CTA seem to be quite equivalent as far as disclosure of the total range of regulation processes relevant for self-regulation is concerned, CaV might be somehow more appropriate for the identification of higher-order orienting and monitoring cognitions.

There emerged no differences in strategic and metastrategic self-regulation between successful and less successful learners, as far as on-line data collectd with CaV and CTA like looking forward or backward, skipping pages, or selective allocation of attention to criterion-relevant text information were concerned. Merely, in the CaV condition successful learners spent a higher amount of total time inspecting text information, perhaps indicating more thorough engagement with the instructional material ($t(21) = -2.48$, $p < .05$). Analysis of protocol data gathered with CaV and CTA referring to frequencies of self-regulative activities, resulted in no significant differences between successful and less successful learners. Nevertheless, weaker learners verbalized more often orientations that indicated a "debilitative affective-motivational mode of self-regulation" ($t(21) = 2.49$, $p < .05$) both in the CaV and CTA condition ($t(18) = 3.49$, $p < .01$, $t(18) = 2.51$, $p < .01$, respectively).

Conclusions

We judged CaV as adequate to apply it as an alternative data assessment strategy compared to the think-aloud method. The main advantages of CaV are (a) less tedious protocol analysis, (b) reduced interference with learning, and (c) adequacy to pinpoint situation-specific self-regulative processes during learning from text.

Our findings demonstrated that the frequencies of higher order self-regulative processes differed between CaV and CTA. While in CaV 46% of the verbalizations were interpreted as higher order orienting and monitoring cognitions, in CTA only 30% of the protocol data referred to metastrategic processing. These results are in accordance with the findings of Buechel (1982): Using the method of concurrent thinking aloud in his study, learners foremost reported about strategies such as rereading and paraphrasing and did not mention metacognitive activities very often. However, it should be considered as a possible limitation of CaV that delayed reporting might increase memory deteriorations, although our subjects mentioned problems of reconstruction very rarely.

Neither on-line performance analysis nor off-line analysis of protocol data using CaV demonstrated any substantial differences between successful and less successful learners in the frequency of self-regulatory processes applied. But if the affective-motivational mode of self-regulation was taken into account, poor learners seemed to be more often engaged in debilitative, self-depreciatory state-oriented cognitions (cf. Kuhl, 1987) and orientation towards task-completion instead of active task-involvement (cf. McCombs, 1988). Besides, results concerning differences between proficient and less proficient learners should be considered as preliminary because the experimental design in this study was not sufficiently elaborated to clarify the question of efficacy in self-regulation, but rather to validate CaV. Furthermore, it should be considered that a multiple-choice comprehension test might be insufficient to validly assess learning results. For a more precise diagnosis of learning performance and comparison of learners with different learning results multiple criterion measures should be applied.

The relevance of prior knowledge for learning from instructional text and picture

The role of domain-specific prior knowledge as an important variable moderating the use of self-regulatory processes and as a main determinant of learning success was demonstrated, for instance, in a study of Hasselhorn and Koerkel (1984). They examined the differential relevance of metacognitive components for comprehension and recall of expository texts on soccer. Sixth grade pupils' reading and learning behavior was studied by means of on-line assessment of reading times, lookbacks and special questionnaires designed to tap declarative and procedural aspects of metacognition. Their results reveal that metacognitive components were substantial performance predictors apart from dispositional intellectual abilities and domain-specific prior knowledge components. Besides, the findings of Hasselhorn and Koerkel (1984) indicate that especially for pupils with low domain-specific content knowledge, on-task self-regulation was of outstanding importance for learning success. Foremost, the procedural metacognitive component ("component of flexibility", referring to selective allocation of attention on difficult text passages, and text reinspection intended to fix up comprehension problems) explained a larger amount of variance in the dependent measures of comprehension compared to declarative components of metacognition (e. g. metamemory). Consequently, it may be supposed that in the case of dealing with a new, demanding task like learning from a complex text requiring substantial domain-specific knowledge, procedural self-regulation becomes very prominent.

Especially in the case where novices in a domain are asked to study instructional texts, the potential facilitating effect of pictures as "compensatory instructional media" on comprehension and learning seems obvious: Pictures may provide for an overview, condense important text information, or serve to visualize complex phenomena difficult to be described verbally. Accordingly, if comprehension relevant pictures are integrated in instructional texts and provide for some overlapping, but not totally redundant information, moderate to substantial gains in learning from text can be expected (Levin, Anglin & Carney, 1987). Nevertheless, illustrations should be designed in accordance with the specific instructional demands at hand, i. e. taking into account the

specific instructional objectives and the potential differences in prior knowledge of the learners. Besides, the instructional potential of pictures as text-complementary media should be considered, especially their suitability to delineate the macrostructure of the text or to diminish the complexity of concepts and rules presented in the verbal format by representing, organizing and supplementing linguistic information. Beyond, even informative pictures may fail to foster learning from expository text if picture-oriented instructions directing the learners' attention to the main informational aspects are lacking or unexperienced learners fail to use the pictures effectively (Weidenmann, 1989).

In general, several beneficial cognitive functions may be attributed to text-relevant pictures, e.g. directing attention to important domain-relevant concepts, facilitating spontaneous visual imagery, fostering activation of comprehension-relevant schemata or inducing the construction, elaboration and evaluation of mental models. Accordingly, Levin et al. (1987) assume that learners with different learning prerequisites do not only benefit from pictures differentially, but even the particular function of a picture in an instructional text may depend on the prior domain-knowledge of the subjects. For instance, for students who lack the ability to organize separate pieces of a text into a coherent whole, representational pictures designed to make the content more concrete may function the same way as organizational pictures that provide for an overview do for skilled learners.

Effects of prior knowledge on processing of pictures with different instructional functions in expository texts have been investigated very rarely. In a study conducted by Dean and Enemoh (1983) ninety undergraduate psychology students with high and low prior knowledge of geology were asked to read difficult prose passages concerning the formation of meanders. Three experimental treatments were provided whereby two groups of learners were forced to process a map-like organizer either before or after they read the passage, while a control group was given no pictorial support. The results demonstrate that subjects with little prior knowledge who were provided with the organizer prior to reading recalled at a level similar to those subjects with a good deal of background knowledge. Besides, the group that received the picture after reading remembered less idea units and performed no better than the learners who were not presented a picture. Particularly,

the pictorial organizer appeared to have had an equalizing effect, bridging the advantage due to prior knowledge in geology. Dean and Enemoh (1983) conclude that the pictorial organizer in the primary position had helped the learners to construct the relevant schemata and interpretative framework necessary for the understanding and anchorage of the information contained in the passage. Summing up, findings were interpreted as support for the use of pictures with an organizing and orienting function in the primary position of connected discourse to aid comprehension, especially for learners with low learning prerequisites.

Joseph and Dwyer (1984) investigated whether domain-specific prior knowledge affected tenth grade public school students processing of instructional text and picture concerning anatomy and physiology of the human heart. To evaluate the instructional effectivity of various types of pictures, different visuals were provided: simple line drawings, realistic photographs and "hybrids", including elements from line drawings and real photos. To assess performance four criterion measures were applied referring to comprehension and retention of information presented in text and pictures. Succinctly, the results indicate that students with high entering behavior achieved equivalent or significant higher scores on the criterion measures than students with low prior knowledge of the content, regardless of the type of visualization. Nevertheless, the use of visualization was an effective instructional means to complement instruction for reducing differences in domain-specific level of achievement. While the various types of visuals were equally effective for subjects with little prior knowledge in the subject content, students with high level of prior knowledge especially profited from the realistic visualization. These findings lend some support to the notion that increased level of prior knowledge of the subject may facilitate the utilization of more realistic and complex visuals or illustrations which integrate abstract and realistic visualization.

Study 2

Objectives

In study 2 CaV was applied to assess observable learning activities during study of a computer presented text on-line, to

examine self-regulatory on-task cognitions elicited retrospectively by means of videoreconstruction, and to explore which cognitive functions and processes were associated with the inspection of a comprehension-relevant organizational picture. Besides, effects of prior knowledge on text learning and picture processing were to be analysed. Therefore, we extended our computer system to provide for flexible and optional presentation of text-embedded pictures if learners asked for the supplementary illustrative information. Moreover, to improve the validity of reconstructed cognitions, the procedure of video-reconstruction was modified. The first study revealed that some subjects reported problems in post-task thinking aloud during the dialogue of reconstruction. Accordingly, we improved CaV to provide for more retrieval cues, intended to facilitate recall of cognitions of those phases of learning being supposed to be indicative of local self-regulation during learning. To stimulate reconstruction of process-centered cognitions, students were not only offered a video-excerpt of selected critical events where they pertained very long at specific portions of text and picture, but also with a time accelerated computer-replay of their learning sequence up to the critical event under discussion. The modified procedure of CaV is depicted in figure 1.

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insert figure 1 about here

In accordance with the first study differences in self-regulatory activities between successful and less successful learners were of special interest. Particularly, we intended to clarify whether the negative results that emerged in the first study, revealing no substantial relationship between self-regulatory activities and learning results, could be replicated. To provide for a more precise assessment of learning performance in the second study we developed two criterion measures depicting on comprehension and knowledge application.

The following hypotheses were to be analysed: <u>Firstly</u>, we supposed that successful learners allocate their attention strategically to criterion-relevant text information, regulate their learning flexible and goal-adaptive and solve comprehension problems by skipping forward and backward in the text to reread

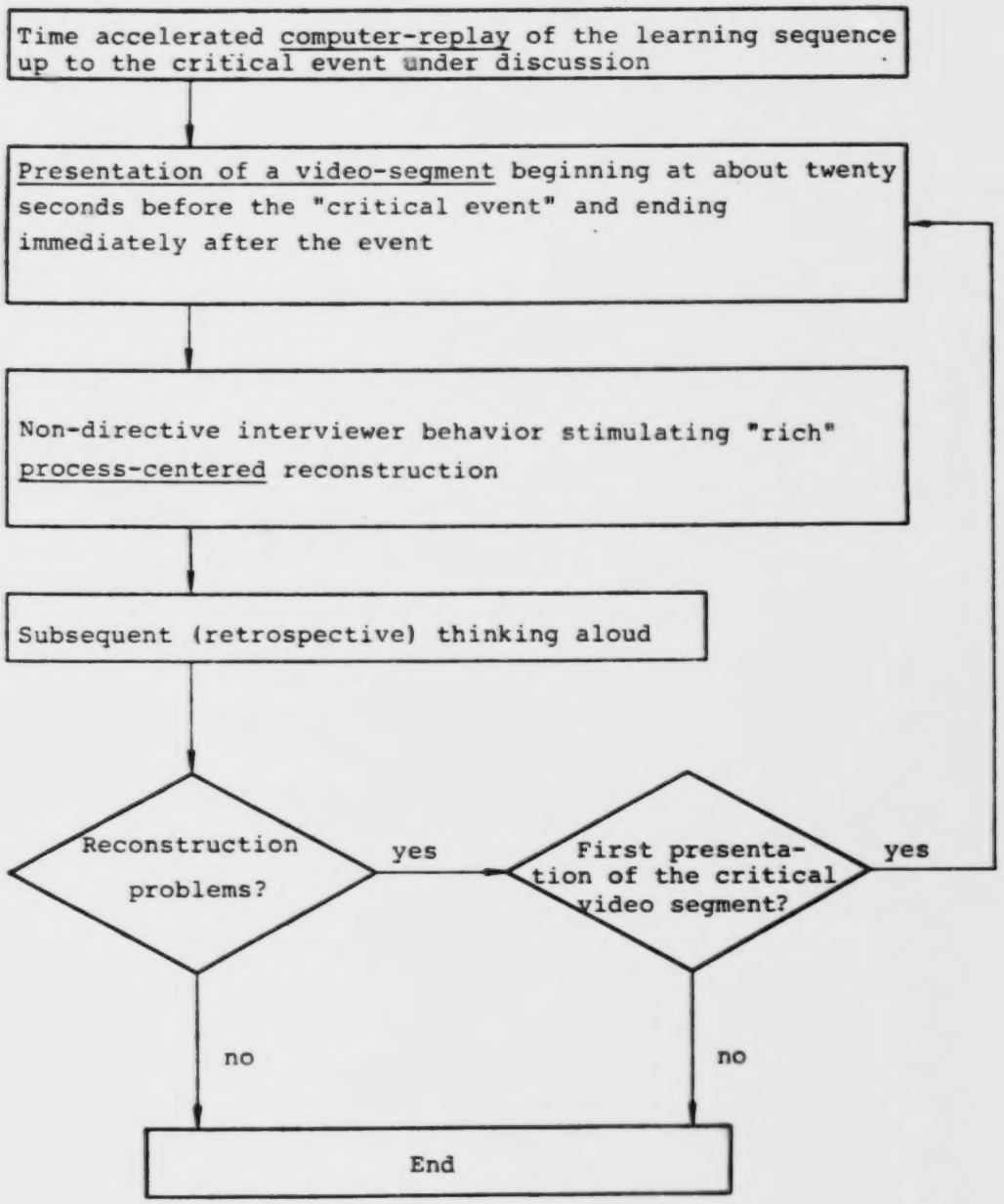
Time accelerated computer-replay of the learning sequence up to the critical event under discussion
Presentation of a video-segment beginning at about twenty seconds before the "critical event" and ending immediately after the event
Non-directive interviewer behavior stimulating "rich" process-centered reconstruction
Subsequent (retrospective) thinking aloud
Reconstruction problems?
yes
First presentation of the critical video segment?
yes
no
no
End

Figure 1. Procedure of Computer-assisted Vidoereconstruction: "Cycle of Reconstruction"

instructional relevant passages. Besides, we assumed that successful learners use the organizational and representational pictures provided more often and more intensive than poor learners to foster text comprehension and recall. As far as the reconstruction of cognitive processes during learning is concerned, verbalizations of proficient learners should refer to both strategic-operative processes and higher-order self-regulatory activities (e. g. orientation, planning, monitoring) and reveal a facilitative affective-motivational mode of self-regulation.

Secondly, as far as effects of prior knowledge are concerned, we speculated that functions and benefits of pictures may differ with respect to learning prerequisites. Particularly, we supposed that both organizing and representational pictures provided as text-complementary information in our study, facilitate learning, but the "post-novices" (e. g. learners with substantial domain-specific knowledge) in the domain at hand profit more from the organizational pictures, that required some knowledge about domain-specific terms and concepts. In contrast, the representational pictures, facilitating visualization of realistic phenomena are more helpful for novices. Besides, it was hypothesized that lack of prior knowledge results in a need for more self-regulative activities during learning from text. Consequently, we thought that in the reconstruction phase of CaV novices report more often about higher order self-regulative activities focusing on encoding, comprehension, remembering, and recall. Moreover, in comparison with post-novices, they must deal more actively with the text material, e. g. focusing selectively on elementary concepts in the domain and demonstrating more skipping backward in the text to clarify their understanding. Because of the fact that post-novices have a more extensive, differentiated and content-specific knowledge base, compared to novices, they are better capable to integrate new information into their existing knowledge structure. Consequently, they are more successful both in the comprehension test and in the knowledge application task.

Method

Thirty-two university students of geography and social sciences with different degrees of domain-specific prior knowledge were

asked to study instructional text including comprehension-relevant pictures dealing with elementary meteorology. Therefore, an expository text (about 3000 words) that contained concepts and rules both relevant and irrelevant for local weather forecasts - including information concerning prognostic significance of clouds, temperature, atmospheric humidity - was presented on the computer screen, using our specially designed computer system providing for a learner-controlled text window. Ten representational pictures were integrated in the text depicting the spatial arrangement, realistic appearance and configuration of different types of clouds. An additional organizational picture was included at the beginning of the text providing for an overview of the main concepts and condensing the macrostructure of the text. Pictures could be inspected on the computer display at will during learning by pressing the mouse buttons. Thereby, the text was faded out and the (full-screen) picture was displayed in high-resolution graphic mode.

Subjects were asked to study text and pictures selectively to gain knowledge helpful to meet the demands of the learning criteria, i. e. comprehension of the main concepts and rules relevant for local weather forecasts. After videoreconstruction of cognitive processes referring to a sample of five "critical" events during reading and picture inspection, subjects were asked to answer multiple-choice comprehension questions. Besides, they were tested for knowledge application, i.e. they had to predict short-range weather development from different meteorological information. Therefore, multiple-choice items including both visual and verbal information about various weather situations were presented on the computer screen. To succeed in this demanding application task that required conclusions about possible changes of weather, subjects had to retrieve both internal visual representations of the cloud configurations introduced in the text and to recall the verbal information about significant meteorological concepts.

Results

Whereas in our first study subjects sometimes reported about problems during reconstruction of process-centered cognitions, these difficulties to recall cognitions referring to specific events during the learning process appeared in the second study very rarely. Only seven out of a total of 648 verbal units were

concerned with difficulties to remember cognitions emerging during the critical events selected for videoreconstruction. The supplementation of CaV with a time accelerated computer-replay of the learning sequence during each "cycle of reconstruction" seemed to be adequate to facilitate the recollection of cognitive processes during learning. This finding is supported by some statements of the students in the post-experimental exploration who judged computer-replay as a very effective means to complement video presentation as a post-task cue to foster reorientation in the learning process.

Our results demonstrate that the post-novices, predominantly undergraduate geography students, who had some degree of domain-specific prior knowledge, were not more successful in performance measures than novices. Perhaps, their learning prerequisites were not sufficiently differentiated as far as the specific content of the instructional text (referring to types of clouds and rules for local weather forecasts) was concerned. Besides, data analysis revealed no differences between novices and post-novices in both on-line and off-line variables of self-regulation during learning from text. Nevertheless, some of these variables proved to be important to predict learning performance.

Concerning process variables assessed with our computer system on-line, subjects who inspected more text lines of the criterion relevant passages of the text were more successful in the comprehension test (r =.34, $p < .05$). On the whole, there emerged almost no significant correlations between process and criterion variables if the total sample was analysed.

Interestingly, if the sample was split at the median according to the prior knowledge of the subjects, a differential pattern emerged: The more novices dealt with the text in a flexible and selective manner, i. e. skipped forward in the text, allocated their attention strategically to relevant text passages and focused on descriptions of complex prognostic rules, the better was their achievement in the comprehension test (r= .55, $p < .05$, r= .65, $p < .01$, r= .48, $p < .05$, respectively). According to our hypothesis, it seems that successful novices demonstrated more corrective self-regulative learning activities adequate to foster text comprehension.

For post-novices, a different pattern emerged: On-line variables of self-regulation were not associated with their achievement in the comprehension test. As far as the knowledge

application criterion task was concerned, one behavioral indicator of flexible text processing, i. e. backward page skipping, was related negatively with learning performance (r= -.48, p < .05). Successful post-novices possibly didn't need these corrective activities of text reinspection. Additionally, an indicator of selective text processing proposed by Wollen, Cone, Margres, and Wollen (1985), the standard deviation of cumulated reading times for each text line inspected, was associated with weaker performance in the knowledge application task (r= -.49, p < .05).

This finding and visual inspection of plotted learning sequences of subjects with high prior knowledge generated by our computer system indicate that a rather continuous and steady reading activity with few regressive text inspections was typical for successful post-novices. Yet, it should be considered that the relationship between on-line variables and learning performance with respect to different levels of prior knowledge varied according to the learning criteria applied.

With respect to verbal report data assessed off-line by means of post-task videoreconstruction referring to selected events during the learning process, the following results emerged: Quality of self-regulatory processes (e. g. orientation, monitoring), their strategic-functional focus (e. g. comprehension, retention), the affective-motivational mode of self-regulation (e. g. expectancy of success) and knowledge components activated during learning (e. g. metacognitive or domain-specific knowledge) did not account for differences between novices and post-novices. Besides, quality of self-regulatory activity was not associated with learning results: Neither operative-strategic activities (e. g. elaboration, memorizing) nor higher-order metacognitive regulation processes (e. g. monitoring) predicted achievement in text comprehension or knowledge application. Even, when self-regulatory processes were reanalysed according to their affective-motivational bias, for instance orientation or monitoring processes revealing a debilitating state-orientation according to Kuhl (1987), no statistical significant correlations with performance measures appeared. These findings are obviously in opposition to our hypothesis that self-regulatory cognitions are predictors of learning outcome.

However, the strategic-functional focus of students' self-regulatory activities (retention and recall) was associated with

learning performance: Independent of the quality of self-regulatory activities verbalized, subjects achieved higher comprehension scores if they directed their cognitive endeavour towards retention (r =.48, $p < .01$) and took into account recall and application of their knowledge acquired to master the final performance tests (r =.35, $p < .05$). Furthermore, post-novices performed better in the knowledge application task if they verbalized cognitions that indicated that their learning activities were intended to improve comprehension (r= .51, $p < .05$). This result suggests that prediction of learning performance may be improved if we look for the particular objectives of students' cognitive enterprise and the goal-directedness of their self-regulation than for the specific cognitive or metacognitive strategies applied.

Regarding our hypothesis that the pictures provided induce several functions during information processing and stimulate different cognitive and metacognitive processes, supportive evidence was provided by both on-line and off-line data: Frequency and duration of picture inspection assessed on-line differed with respect to prior knowledge and was related to learning results.

For novices, time for the inspection of the organizational picture and frequency of inspecting the representational pictures were positively related to success in the comprehension test (r= .44, $p < .05$, r= .47, $p < .05$, respectively). Obviously, both types of pictures were effective instructional media for students with low domain-specific knowledge, possibly providing for orientation on the macrostructure of the text, visualizing content-related concepts explicated in the text, and fostering comprehension during text processing. No corresponding positive relationship between picture inspection and performance occurred with respect to the knowledge application task. Perhaps, this criterion measure was too challenging for novices. Besides, success in the knowledge application (near transfer) test required not only knowledge about information presented in the pictures, but also a combination of conceptual and procedural knowledge in the domain of meteorology provided in the text as a prerequisite to make conclusive inferences necessary for a local weather forecast.

For post-novices, a different pattern emerged: While picture inspection was not related to achievement in the comprehension test, it was negatively associated with knowledge application: The

more successful post-novices were in the knowledge application task, the less often and long they inspected the organizational picture (r= -.60, p < .01, r= -.60, p < .01, respectively). Moreover, utilization of representational pictures was neither related to text comprehension nor to knowledge application. Accordingly, the quantitative behavioral indicators of picture inspection do not demonstrate the beneficial function of the organizational picture assumed especially for subjects with higher domain-specific knowledge. Perhaps, strategic text processing was more relevant than picture inspection for post-novices.

Verbal report data assessed off-line by means of videoreconstruction, concerning "critical events" where subjects inspected the picture with an organizational function, were analysed by means of categories focusing on different cognitive and metacognitive processes elicited during picture inspection and on the cognitive and affective-motivational functions of pictures. Examination of verbal report data demonstrates that self-regulatory processes and functions elicited by the organizational picture did not differ between novices and post-novices. The picture was beneficial for all learners, especially for memorizing (24 out of a total of 124 verbalizations) and metacognitive regulation processes, i. e. it stimulated orientation (16 verbalizations) and monitoring of text comprehension (33). The organizational picture was not only functional for encoding relevant information of the text (23 out of 120 verbalizations), but also to support retention (52) and comprehension (21). These findings give support to the assumption that executive regulation processes elicited during picture inspection play an important role in the course of learning from illustrated text.

Conclusions

Taken together, findings demonstrate that there are some substantial relations between on-line variables of self-regulation assessed with our computer system - particularly selectivity and flexibility of reading and learning activities - and learning performance in both text comprehension and knowledge application. In contrast, verbal report data assessed off-line by means of videoreconstruction did not give support to the hypothesis that quality of cognitive self-regulation is a potential predictor of learning outcome. Rather, goal-directedness of cognitive and

metacognitive regulatory activities applied, independent of their specific quality or affective-motivational orientation, was associated with learning success.

Interestingly, correlations between process variables and learning success were often different for novices and post-novices, and not always consistent for the two criterion measures. Particularly, novices performed better in the comprehension test if they looked ahead in the text flexibly, indicating a forward search strategy, and allocated their attention strategically on criterion-relevant text passages, especially those dealing with complex rules. For post-novices, the on-line indicators of strategic text processing were not related to learning performance - except for the unexpected finding that skipping backward in the text was related negatively to learning results in knowledge application. On the whole, these results might indicate that self-regulation during learning from text is especially relevant for novices in a specific domain.

As far as picture utilization was concerned, our findings give support to a differential, performance-specific expertise-effect: While for students with higher domain-specific prior knowledge picture inspection was not related to the post-task comprehension measure, a strong negative correlation emerged between both frequency and duration of inspection of the organizational picture and performance in the final knowledge application test. Perhaps, for post-novices careful processing of the text was a more efficient strategy to gather knowledge necessary for successful achievement in the complex knowledge application task than to inspect excessively the organizing picture that provided only for conceptual information not sufficient to derive the rule-based inferences required. In contrast, subjects with low prior knowledge accomplished better in the comprehension-related criterion test if they both inspected the representational pictures very often and spent some substantial amount of time examining the organizational picture. It may be supposed that the organizational visual we had selected to condense the macrostructure of the instructional text "cued" domain-relevant concepts explicated in the text in a more detailed manner.

According to our findings a preliminary prescriptive conclusion may be derived: First, both organizational and representational pictures integrated in a complex instructional text with the intention to foster orientation, comprehension, and

retention may be effective to supplement textual information and to enhance performance, specifically if the recipients have only low domain-specific prior knowledge available. Second, to increase the situation-appropriate use of comprehension-relevant pictures for novices, additional instructional support, e.g. special processing instructions that encourage readers to focus on the relevant information, may be helpful to direct their attention to the illustration, to motivate them to invest mental effort for "deep" picture processing and to aid the extraction of pictorial-imaginal information.

With respect to verbalizations assessed retrospectively by means of videoreconstruction referring to events during learning where the organizational picture was inspected, we performed a more detailed content-analysis separating the functions stimulated by this picture and the cognitive and metacognitive processes associated with picture inspection. Interestingly, analysis of protocol data revealed that functions actually stimulated by this picture varied considerably between learners. Specifically, the picture did not only provide for orientation referring to the macrostructure level of the textual information, but enhanced subjects' encoding, comprehension and recall of instructional relevant information as well. This finding indicates that future research dealing with illustrations as adjuncts in instructional texts should look in detail what kind of mental processes learners are actually engaged in whilst processing the pictorial information. As far as processes associated with picture inspection were concerned, a very interesting finding emerged: Inspection of the organizational picture was not only associated with cognitive processes referring for instance to memorization or elaboration, but to metacognitive processes as well, especially orientation about task-specific boundary conditions, instructional goals and monitoring of the cognitive enterprise. Consequently, taxonomies referring to functions of pictorial-imaginal information (cf. Levin et al., 1987) should be extended to incorporate the beneficial effects of illustrations as possibly very influential tools to facilitate higher-order component processes of executive self-regulation during learning.

On the whole, our results demonstrate that an experimental arrangement like CaV may be appropriate to collect rich on-line and off-line data concerning differences in strategic, self-regulatory text processing. Additionally, CaV may provide new

insights into the benefits and limitations of pictures with instructional text, especially referring to cognitive and metacognitive processes elicited during inspection of pedagogical substantial pictures.

Furthermore, CaV may be applicable to shed more light on the question of how pictures are actually used during learning from complex instructional text, particularly to clarify when, where and how pictures are inspected by different kind of students with varying learning prerequisites. Besides, our experimental arrangement may be used to clarify specific prescriptive issues in educational psychology referring to the optimization of the design of effective text-picture combinations to enhance learning, the development of additional processing instructions that encourage learners to actively encode, represent and remember information that is provided in the pictorial format, and to evaluate instructional course material requiring for relational processing of both text and picture.

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